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Effectiveness of a Co-Created Multimodal Behavioural Change Model for Improving Infection Prevention and Control Practices Among Healthcare Workers in Conflict-Affected Goma, Democratic Republic of the Congo: A Quasi-Experimental Study

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Abstract:

- ***Background:***

Nosocomial infections constitute a major threat to patients' safety in low-resource contexts, where healthcare workers' (HCWs') limited knowledge of infection prevention and control (IPC) combined with poor working conditions and workload can exacerbate the risk of healthcare-associated infections. Few studies have investigated the effectiveness of co-created, context-specific, multimodal interventions to improve knowledge, attitudes, and practices (KAP) related to IPC in such settings.

- ***Objective:***

We aimed to assess the effectiveness of a co-created, seven-component multimodal behavioural change model to improve IPC-related KAP among healthcare workers in three hospitals in Goma, Democratic Republic of the Congo.

- ***Methods:***

A quasi-experimental mixed methods study compared a hospital receiving the intervention (n=142 Healthcare workers (HCWs)) with two comparison hospitals (n=142 HCWs) at baseline and endline. A Goma Infection Prevention and Control Behaviour Change Model (GIPCM) was co-created with key-informant interviews (n=12), focus group discussions (n=8) and a stakeholder workshop. The effectiveness of the intervention was evaluated using 20 indicators of knowledge, 15 indicators of attitude, and 15 indicators of practices. Mixed-effects logistic regression with an interaction term of time-by-group was used to estimate difference-in-differences (DiD).

- ***Results:***

The intervention and comparison groups were well balanced at baseline (all p>0.05 except hospital department). Stakeholders reported that the co-created intervention was relevant (4.8/5), acceptable (4.5/5), feasible (4.2/5) and sustainable (4.1/5). The intervention had a significantly greater effect than the comparison on 12 out of 20 knowledge indicators, 5 out of 15 attitude indicators, and 9 out of 15 practice indicators (all p<0.05). Larger practice effects were observed for discarding sharps without recapping (DiD=+30.9 percentage points) and hand hygiene before direct patient contact (+21.9), participation in IPC training (+21.2), peer support for compliance (+18.4), and appropriate personal protective equipment (PPE) removal and disposal (+17.6). Larger effects were seen for domains with the lowest baseline performance and for practices which did not rely on material resources. High patient-to-staff ratios, lack of PPE and consumables, unreliable water supply and overcrowding were reported as major barriers, consistently across the intervention and the comparison groups.

➢ ***Conclusion:***

Context-specific co-created, multimodal behaviour change interventions can improve IPC-related knowledge, attitude and practices of healthcare workers in a low-resource, conflict-affected setting, but addressing the structural drivers of poor IPC will require increased investment in staffing, material resources, water and sanitation, surveillance, and supervision.

Keywords: *Infection Prevention and Control; Nosocomial Infection; Healthcare Workers; Co-Creation; Multimodal Strategy; Behaviour Change; Difference-in-Differences; Democratic Republic of the Congo.*

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I. INTRODUCTION

Healthcare-associated, or nosocomial, infections, are one of the most pressing challenges for patient safety worldwide, posing a disproportionate threat to patients in low- and middle-income countries where healthcare workers (HCWs) have reduced diagnostic and surveillance capabilities and limited infection prevention and control (IPC) resources (World Health Organization, 2022; Allegranzi et al., 2022). The World Health Organization has prioritized IPC as a global health priority for 2021-2030, estimating that effective IPC programmes may reduce healthcare-associated infections by up to 70% (World Health Organization, 2022). However, implementing global IPC guidance in fragile health systems where HCWs have inadequate supplies and staffing remains a significant challenge (Asghar et al., 2025; Alhumaid et al., 2021).

The WHO multimodal improvement strategy, which incorporates system change, training, monitoring and feedback, reminders, and institutional safety climate, has been the most widely used strategy to improve IPC practice and has proven effective in various healthcare settings (World Health Organization, 2009, 2016). However, systematic reviews of IPC interventions in African healthcare facilities highlight significant variability in intervention effectiveness while noting that few studies have employed rigorous quasi-experimental studies that engaged end-users in intervention design (Igwe et al., 2024; Demoze et al., 2026). Reviews of healthcare workers' compliance with IPC practices consistently report knowledge gaps, unfavourable attitudes and structural barriers, including inadequate personal protective equipment (PPE), reliable water supply, and excessive workloads, as hindrances to good practice in sub-Saharan Africa (Alhumaid et al., 2021; Dubiwak et al., 2026; Wubneh et al., 2024).

Goma, the capital of North Kivu Province in the eastern Democratic Republic of the Congo (DRC), is a prime example of conflict-affected, under-resourced healthcare system with urbanization pressures. Decades of armed conflict have led to significant displacement, unplanned urbanization, and chronic strain on an already inadequate health system (Office for the Coordination of Humanitarian Affairs, 2023; World Bank, 2022). Hospitals in Goma suffer from a lack of water, consumables, and staff, as well as overcrowding and the absence of continuous professional training, increasing nosocomial infection risk despite an apparent dedication from healthcare workers. However, there are few contextually adapted, rigorously evaluated IPC interventions for such a conflict-affected urban health system in the published literature.

A further challenge regarding the implementation of IPC interventions is that behaviour change strategies are often externally developed and consistently applied, with limited adaptation to local health system constraints or engagement with the healthcare workers who will implement them, reducing the acceptability and appropriateness of the interventions for the local context (Houghton et al., 2020). Co-creation interventions, which engage these stakeholders in problem diagnosis and solution design, have been associated with better contextual relevance, acceptability, and sustainability of health interventions more generally (Bate & Robert, 2006; Donetto et al., 2014), however, they have rarely been evaluated using a controlled design regarding behaviour change in African hospitals in conflict-affected regions.

This study aimed to evaluate the effectiveness of a co-created, contextually adapted multimodal behavioural change model, the Goma Infection Prevention and Control Behaviour Change Model (GIPCM), among healthcare workers at Goma, DRC. The model was built using a structured, participatory process of key-informant interviews, focus group discussions and a stakeholder validation workshop that retained the five pillars of the WHO multimodal improvement strategy while adding two components addressing supply security and water, sanitation, and hygiene (WASH) infrastructure. This study aimed to (i) co-create and validate a contextually appropriate multimodal behavioural change model for nosocomial infection prevention with healthcare workers and stakeholders in Goma, and (ii) investigate the effect of the resulting model on improving healthcare workers' IPC-related knowledge, attitudes, and practices, using a quasi-experimental, difference-in-differences design to compare an intervention hospital to two comparator hospitals, comparing baseline to endline data. The study is therefore contributing to the body of research by generating mixed methods evidence around the value of co-creation as a strategy to improve IPC behaviours, in a fragile, under-resourced urban health system.

II. MATERIALS AND METHODS

➢ *Study Design*

A quasi-experimental mixed-sequential design was adopted to assess the effectiveness of a co-created multimodal behavioral change model in improving knowledge, attitude, and practices (KAP) towards nosocomial infection prevention among healthcare workers. The study employed a nonequivalent intervention and comparison group pretest-posttest design where a pre-test (baseline) and post-test (endline) of KAP by HCWs were compared. The co-created behavioral change model was instituted among participants in the intervention hospital, while HCWs in the comparison hospitals continued with business as usual with respect to IPC practices, with a post-intervention endline assessment conducted at all three hospitals. This study also included a qualitative component consisting of key-informant interviews (KIIs), focus group discussions (FGDs), and a co-creation workshop to elucidate the contextual determinants of IPC behavior and to co-create the intervention under investigation. A quasi-experimental design was considered appropriate and preferable to individual-level randomization, as randomization at the individual level would risk contamination of both arms if participants within the same hospital were randomized, while allocation at the hospital level would maintain a clear comparison while retaining ecological validity for a hospital-based intervention (Creswell & Plano Clark, 2018).

➢ *Study Setting*

The study was conducted in Goma, the capital of North Kivu Province in the eastern Democratic Republic of Congo (DRC). This city is located on the northern shore of Lake Kivu and has a population of approximately 841000 people. The city has experienced significant population growth, both through natural increase and as a result of more than 500000 people fleeing recurrent armed conflict in the surrounding areas (“Office for the Coordination of Humanitarian Affairs,” 2023). Over 70% of households in the city live below the national poverty level, and out-of-pocket payments are the primary method of financing healthcare in the country (“World Bank,” 2022). There are three general referral hospitals in the city. La Charité Maternelle Hospital in the Goma Health Zone was the intervention site for the study, where the adapted multimodal programme was implemented. CBCA Virunga Hospital in the Karisimbi Health Zone and Minova General Referral Hospital in the neighbouring South Kivu Province were the comparison sites. Minova General Referral Hospital is farther away from Goma than the other two hospitals, which reduces the likelihood of contamination between the study arms.

➢ *Study Population, Sampling, and Sample Size*

The study population consisted of clinical and non-clinical healthcare workers in the two Goma health zones, which totalled approximately 2,300 staff, including physicians, nurses, midwives, laboratory technicians, hygienists, and administrative personnel. Eligible HCWs for inclusion were those with direct or indirect patient contact who had been employed at their facility for at least six months at baseline (or, for the co-creation phase, purposefully identified HCWs and managers with relevant IPC experience/decision-making responsibility) and were not on extended leave, short-term trainees, or otherwise provided substantially incomplete response sets. Eligible HCWs were identified using a multistage sampling procedure: Health facilities were purposefully selected as intervention or comparison sites; eligible HCWs from these facilities were stratified by professional cadre; and participants were selected from each stratum by simple random sampling to reduce potential selection bias and ensure representation across cadres (World Health Organization, 2003, 2021).

The required sample size was determined using the formula for comparing two independent proportions (Fleiss, Levin, & Paik, 2003), assuming a baseline proportion of adequate IPC practice of 50% and an anticipated post-intervention proportion of 70% (a 20-percentage-point minimum detectable difference), at 95% confidence and 80% power. This resulted in a base requirement of 91 HCWs per group; after accounting for a design effect of 1.5 and anticipated 10% non-response, the target sample size was 153 HCWs per group (306 total). The study enrolled 284 HCWs who completed both baseline and endline questionnaires (142 per arm), which is a response rate of 92.8% and exceeds the commonly recommended minimum of 80% for survey-based research and reduces the likelihood of substantial non-response bias (Fincham, 2008).

➢ *The Co-Created Intervention: Development of the GIPCM*

The intervention was developed following a co-creation process involving twelve key-informant interviews (KIIs) with hospital managers, infection control (IPC) focal persons, and provincial authorities; eight focus group discussions (FGDs) with a total of n=48 frontline health workers; and a one-day co-creation workshop involving twenty participants. The qualitative findings from KIIs and FGDs were thematically analysed using deductive and inductive approaches. The former was informed by the World Health Organization (WHO) multimodal IPC framework, whereas the latter sought to understand the contextual issues affecting IPC in the hospitals. The analytical findings were used to build a conceptual model of behaviours and evidence-based interventions to improve IPC in the hospitals. The final conceptual model, which was named the Goma Infection Prevention and Control Behaviour Change Model (GIPCM), built on the five multimodal pillars of WHO system change, training and education, monitoring and feedback, reminders, and institutional safety climate and added two components identified during the interviews and discussions. These included sustainable system and supply security and water, sanitation, and hygiene (WASH). The seven-component model was developed using terminologies familiar to the participants and local languages (Swahili). Specifically, the components were labelled: MABADILIKO (system change and supply security), SOKO (education and practical skills), SIMAMIZI (monitoring, audit, and feedback), KUMBUKA (reminders), RAFIKI (peer support and safety culture), UONGOZI (leadership and governance), and MAJI (WASH and environmental hygiene). The model and its components were evaluated by the twenty participants who took part in the co-creation workshop using four criteria: relevance,

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feasibility, acceptability, and sustainability. The participants scored each criterion on a five-point Likert scale, with scores guiding the subsequent implementation of the model in the intervention hospital.

➢ *Data Collection Instruments*

Three research instruments were employed in the study. Structured questionnaires administered to health care workers assessed knowledge (20 items), attitudes (15 items), and practices (15 items) on preventing nosocomial infections. The questionnaire was pre-tested by 50 respondents and was found to have an acceptable Cronbach's alpha internal consistency reliability score of 0.85. A semi-structured interview guide was used to conduct key-informant interviews and focus group discussions to elicit the perspectives, experiences, and expectations of healthcare workers and stakeholders towards IPC. An observational checklist was also used to observe hygiene practices in a blinded manner to avoid observer bias. Research instruments and materials were standardized, and data collectors recruited from the Centre for Research on Sustainable Development in Africa (CREDDA) at the Université Libre des Pays des Grands Lacs underwent training on ethical aspects, research protocols, and data quality assurance procedures prior to data collection. Double data entry and field supervision were employed to ensure quality.

➢ *Data Analysis*

Data were analysed using SPSS version 29. For the baseline analysis, categorical variables were summarised as frequencies and percentages and compared between arms by Pearson's chi-square tests, while continuous variables were summarised as means and standard deviations, compared using independent-samples t-tests. Thematic analysis combined deductive coding informed by the WHO multimodal framework and inductive coding to capture themes; stakeholder validation ratings were summarised using mean scores across the four criteria. To evaluate intervention effectiveness, we compared change in each KAP indicator between baseline and endline in the intervention and comparison groups using mixed-effects logistic regression models specifying a time-by-group interaction term, which isolates the intervention-specific change beyond any secular change observed in the comparison group; results are reported as difference-in-differences percentage-point estimates, interaction odds ratios (ORs) with 95% confidence intervals and p-values, with significance threshold a priori set at $p<0.05$. Hospital department is an important covariate given the significant baseline imbalance between arms and was incorporated as such in effectiveness models. We analysed perceived individual barriers to effective IPC practice descriptively, grouped into systemic/infrastructural, administrative/managerial, and individual/behavioural domains, with between-arm comparisons using Pearson's chi-square tests and odds ratios, treating responses as non-mutually exclusive.

➢ *Ethical Considerations*

This study has been approved by Great Lakes University of Kisumu (GLUK) Scientific and Ethical Review Committee, National Ethics Committee of the Democratic Republic of the Congo, as well as by the administration of each participating hospital. Verbal informed consent was sought from all participants before collecting any data, and a commitment to confidentiality and anonymity was secured. Participants of comparison hospitals were assured that the intervention package would be available to them after the endline survey, as is usually the case with delayed intervention designs.

III. RESULTS

➢ *Response Rate and Baseline Characteristics of Participants*

The study reported that the response rate was one hundred percent with two hundred and eighty-four out of three hundred and six healthcare workers selected. Out of those selected, one hundred and forty-two were chosen from the experimental group, and one hundred and forty-two were from the control group. Table 1 below contains the baseline survey results for the participants selected. The overall mean age of the sample was 32.8 years (SD=6.9), as opposed to roughly equal mean ages (32.5 and 33.1 years) for the intervention and comparison groups, respectively ($t=0.734$, $df=282$, $p=0.466$). Males made up 59.2% of the sample, while nurses comprised the single biggest professional cadre at 40.8%, closely followed by physicians and medical officers who accounted for 19.7%. The age category, gender, professional cadre, and years of clinical experience were statistically equivalent in the two trial arms (all $p>0.05$). The hospital department, on the other hand, varied significantly between the trial arms ($\chi^2=19.342$, $df=5$, $p=0.002$). The intervention group recorded a higher average percentage of staff from Internal Medicine (29.6%) and a lower average percentage in Surgery/Operating Theatre (25.4%) compared to the counterparts (14.1 and 10.6%, respectively). This imbalance warranted controlling for the effect of department in the effectiveness models discussed in Section 3.3.

Table 1 Baseline Sociodemographic Characteristics of Healthcare Worker Participants (N = 284)

Variable	**Category**	**Intervention (n=142) n (%)**	**Comparison (n=142) n (%)**	**Total (N=284) n (%)**	**χ^2 / t**	**df**	**p**
Age in years, Mean (SD)		32.5 (6.8)	33.1 (7.0)	32.8 (6.9)	t=0.734	282	0.466
Age category	20-29 years	43 (30.3)	46 (32.4)	89 (31.3)	χ^2=0.221	3	0.974
	30-39 years	59 (41.5)	58 (40.8)	117 (41.2)			
	40-49 years	28 (19.7)	27 (19.0)	55 (19.4)			
	≥50 years	12 (8.5)	11 (7.7)	23 (8.1)			

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Gender	Male	80 (56.3)	88 (62.0)	168 (59.2)	χ^2=0.932	1	0.335
	Female	62 (43.7)	54 (38.0)	116 (40.8)			
Professional cadre	Nurse	60 (42.3)	56 (39.4)	116 (40.8)	χ^2=1.345	5	0.931
	Physician/Medical Officer	26 (18.3)	30 (21.1)	56 (19.7)			
	Pharmacy Technologist	16 (11.3)	14 (9.9)	30 (10.6)			
	Laboratory Technologist	13 (9.2)	15 (10.6)	28 (9.9)			
	Midwife	15 (10.6)	13 (9.2)	28 (9.9)			
	Hygienist/Support Staff	12 (8.5)	14 (9.9)	26 (9.2)			
Years of clinical experience	<5 years	57 (40.1)	59 (41.5)	116 (40.8)	χ^2=0.081	2	0.961
	5-10 years	57 (40.1)	55 (38.7)	112 (39.4)			
	>10 years	28 (19.7)	28 (19.7)	56 (19.7)			
Hospital department	Internal Medicine	42 (29.6)	20 (14.1)	62 (21.8)	χ^2=19.342	5	0.002**
	Emergency/ICU	30 (21.1)	30 (21.1)	60 (21.1)			
	Surgery/Operating Theatre	15 (10.6)	36 (25.4)	51 (18.0)			
	Paediatrics/Neonatology	25 (17.6)	26 (18.3)	51 (18.0)			
	Maternity Ward	18 (12.7)	12 (8.5)	30 (10.6)			
	Gynaecology/Obstetrics	12 (8.5)	18 (12.7)	30 (10.6)			

*Note. χ^2 = Pearson's chi-square statistic; t = independent-samples t statistic; df = degrees of freedom. Percentages are calculated within the respective group total and may not sum to exactly 100% due to rounding. ** p < 0.01.*

➢ *Baseline Knowledge, Attitudes, and Practices, and Co-Creation of the GIPCM*

At baseline, healthcare workers in both arms demonstrated a generally positive orientation towards IPC as a professional responsibility, alongside significant gaps in technical knowledge and application. Knowledge gaps were highest for the WHO Five Moments for Hand Hygiene (45.1% and 40.8% correct in the intervention and comparison groups, respectively), the indication for alcohol-based hand rub (52.8% and 49.3%), the misconception that used needles should be recapped (33.8% and 36.6% correctly rejecting), the scope of standard precautions (39.4% and 43.7%), and correct knowledge of environmental surface cleaning (36.6% and 40.8%). Favourable attitudes were high for the need of IPC supplies (93.0% and 90.8%) and cross-cadre teamwork (90.1% and 87.3%) but low for the practicality of hospital IPC guidelines (43.7% and 40.8%) and confidence in leadership's commitment (38.7% and 35.9%). Compliance was best with disinfecting reusable instruments (78.9% and 74.6%) and worst with discarding sharps without recapping (38.0% and 40.8%) and documenting or reporting observed IPC lapses (29.6% and 26.8%). None of the baseline KAP indicators differed significantly between the intervention and comparison groups (all p>0.05), establishing baseline comparability.

Thematic analysis of 12 key-informant interviews and eight focus group discussions revealed five interrelated priority problems for poor IPC performance: chronic shortages of water, PPE, and consumables; a persistent gap between HCWs' theoretical knowledge and their hand's-on competence; the absence of routine, supportive monitoring and feedback; weak behavioral cueing at the point of care; and inconsistent institutional leadership and accountability for IPC. These problems were mapped, via the co-creation workshop, to the seven-component Goma Infection Prevention and Control Behaviour Change Model (GIPCM) summarized in Table 2, which expands the five WHO multimodal pillars by two locally identified components addressing supply security and WASH infrastructure. As one IPC focal point observed of the resulting model, it was "not something from Geneva or Kinshasa that someone drops on our desk," but something constructed from locally identified problems and solutions.

Table 2 The Co-Created Goma Infection Prevention and Control Behaviour Change Model (GIPCM)

Mode	Component	Objective	Key strategies
1	MABADILIKO - System Change and Supply Security	Ensure permanent availability of water, PPE, disinfectants, and functional infrastructure	Dedicated IPC budget; supply dashboard; reorder triggers; local alcohol-based handrub production; 30-day PPE safety stock; equipment maintenance; leadership advocacy
2	SOKO - Education and Practical Skills	Improve knowledge and convert it into competent practice through repeated hands-on training	Weekly 15-minute micro-sessions; new-staff orientation; PPE simulation; fluorescent-marker

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			validation; case-based learning; mentorship
3	SIMAMIZI - Monitoring, Audit and Feedback	Provide supportive, regular, data-informed monitoring	Monthly observation; immediate feedback; ward scorecards; quarterly audits; routine health information system integration; positive reinforcement
4	KUMBUKA - Behavioural Reminders	Cue desired behaviours at the point of care and counter forgetfulness	Pictorial posters; pocket cards; floor decals; mobile-messaging reminders; auditory cues; visual job aids
5	RAFIKI - Peer Support and Safety Culture	Create positive social norms, constructive peer correction, and collective accountability	IPC champions; correction scripts; buddy system; ward-level recognition scheme; safety huddles
6	UONGOZI - Leadership and Governance	Institutionalise visible and accountable management commitment to IPC	Management pledge; IPC in strategic plans; leadership walk-rounds; functional IPC committees; supply advocacy; IPC in staff evaluations
7	MAJI - WASH Infrastructure and Environmental Hygiene	Ensure reliable water, sanitation, and environmental-cleaning capacity	Borehole/rainwater backup; supplementary handwashing points; colour-coded waste bins; cleaning checklists; weekly spot checks

Note. The GIPCM was co-created through 12 key-informant interviews, eight focus group discussions (n=48), and a one-day stakeholder co-creation and validation workshop (n=20). Components 1-5 correspond to the five WHO multimodal improvement strategy pillars (World Health Organization, 2009, 2016); components 6 and 7 were added to address context-specific structural and governance constraints identified in Goma.

Table 3 Presents stakeholder validation ratings per GIPCM component (mean scores across all stakeholders per item). Overall, all 7 components received ‘high’ relevance and acceptability (overall mean scores > 4.0/5.0 for both criteria), with the majority of components scoring exceptionally high (mean score > 4.5/5.0) on relevance (Table 3). MABADILIKO and UONGOZI scored the highest on relevance (4.9/5.0), which reflects stakeholders’ prioritisation of systemic contextual factors and institutional level leadership, but comparatively lower feasibility (3.8 and 3.6) and sustainability scores (3.5 and 3.5 respectively), reflecting the perception that many of system level factors require structural and budgetary changes, which are more challenging to achieve and maintain over time. In contrast, KUMBUKA (behavioural reminders) and MAJI (infrastructure) scored the highest feasibility ratings (4.8/5.0 and 4.7/5.0 respectively) and among the highest sustainability ratings (4.7/5.0 and 4.6/5.0), suggesting that stakeholders perceive low cost, visible interventions to be relatively easy to implement within the constraints of the local health system.

Table 3 Stakeholder Validation Ratings of the GIPCM Components (n = 20)

GIPCM component	Relevance	Feasibility	Acceptability	Sustainability
MABADILIKO - System Change and Supply Security	4.9	3.8	4.6	3.6
SOKO - Education and Practical Skills	4.8	4.4	4.7	4.2
SIMAMIZI - Monitoring, Audit and Feedback	4.8	3.9	4.3	3.8
KUMBUKA - Behavioural Reminders	4.7	4.8	4.6	4.7
RAFIKI - Peer Support and Safety Culture	4.6	4.3	4.5	4.4
UONGOZI - Leadership and Governance	4.9	3.5	4.4	3.5
MAJI - WASH Infrastructure	4.7	4.7	4.5	4.6
Overall GIPCM	4.8	4.2	4.5	4.1

Note. Ratings are on a 1-5 scale, with higher scores indicating greater perceived relevance, feasibility, acceptability, and sustainability, as assessed by the 20 co-creation workshop participants.

➢ *Effectiveness of the GIPCM on IPC Knowledge*

Table 4 shows the difference-in-differences analysis of correct knowledge responses to 20 IPC items. The intervention was associated with significantly more improvement than the comparison group for 12 of the 20 items (all p<0.05). The largest knowledge effects were in correcting the misconception that used needles should be recapped (DiD=+26.8 percentage points; OR=3.01, 95% CI 1.52-5.97, p=0.002), the WHO Five Moments for Hand Hygiene (+26.1 points; OR=3.14, p=0.001), cleaning of environmental surfaces (+26.1 points; OR=2.93, p=0.002), indication to use alcohol-based hand rub (+25.4 points; OR=3.46, p<0.001), the misconception that gloves substitute for hand hygiene (+24.6 points; OR=2.81, OR=3.010), and the scope of standard precautions (+24.6 points; OR=3.011, OR=3.012). Significant albeit smaller effects were also seen for hand hygiene timing, PPE selection criteria, waste segregation, contaminated linen handling, transmission-based isolation precautions, and continuous surveillance and feedback. In contrast, knowledge items with already-high baseline performance, such as the definition of nosocomial infection (78.9% to 83.8% in the intervention group) and sharps disposal practice, had negligible or null DiD estimates suggesting a ceiling effect. No significant intervention-specific improvement was seen for knowledge of antimicrobial resistance, ward-level infection risk factors, or restrictions on ill healthcare workers returning to duty.

Table 4 Difference-in-Differences (DiD) Analysis of Correct Knowledge Responses Regarding Nosocomial Infection Prevention (N = 284)

No.	Knowledge item	Baseline Interv. %	Endline Interv. %	Baseline Comp. %	Endline Comp. %	DiD (pts)	OR	95% CI	p
1	Definition of nosocomial infection	78.9	83.8	73.9	80.3	-1.4	0.97	0.43-2.19	.934
2	Hand hygiene timing	62.0	87.3	57.7	59.9	+23.2	3.87	1.81-8.31	<.001***
3	Alcohol-based hand rub indication	52.8	81.7	49.3	52.8	+25.4	3.46	1.70-7.05	<.001***
4	WHO Five Moments for Hand Hygiene	45.1	75.4	40.8	45.1	+26.1	3.14	1.57-6.25	.001**
5	Glove-substitution misconception (False)	43.0	69.7	47.9	50.0	+24.6	2.81	1.43-5.52	.003**
6	PPE selection criteria	66.9	88.0	64.1	67.6	+17.6	3.11	1.42-6.84	.005**
7	Needle-recapping misconception (False)	33.8	64.1	36.6	40.1	+26.8	3.01	1.52-5.97	.002**
8	Sharps disposal practice	83.1	87.3	80.3	84.5	+0.0	1.05	0.42-2.58	.922
9	Reusable instrument decontamination	77.5	90.1	74.6	77.5	+9.9	2.28	0.95-5.44	.064
10	Standard precautions scope (False)	39.4	67.6	43.7	47.2	+24.6	2.78	1.42-5.46	.003**
11	Waste segregation	56.3	83.1	52.1	56.3	+22.5	3.21	1.56-6.61	.002**
12	Contaminated linen handling	63.4	84.5	59.9	63.4	+17.6	2.72	1.29-5.71	.008**
13	Transmission-based isolation precautions	69.0	88.0	65.5	70.4	+14.1	2.63	1.19-5.83	.017*
14	Environmental surface cleaning (False)	36.6	66.2	40.8	44.4	+26.1	2.93	1.49-5.78	.002**
15	Device-associated infection prevention	73.2	87.3	68.3	73.9	+8.5	1.91	0.85-4.28	.115
16	Surgical site infection prevention	71.8	78.9	69.7	76.1	+0.7	1.06	0.50-2.26	.878
17	Ward conditions as risk factor	81.0	84.5	76.1	81.7	-2.1	0.91	0.39-2.12	.830
18	Antimicrobial resistance relationship (False)	42.3	50.0	45.8	49.3	+4.2	1.19	0.61-2.30	.612
19	Ill HCW work restrictions	74.6	81.7	70.4	76.1	+1.4	1.14	0.52-2.47	.748
20	Continuous surveillance and feedback	67.6	86.6	63.4	66.9	+15.5	2.66	1.23-5.75	.013*

*Note. Comp. = comparison group; DiD = difference-in-differences; OR = interaction odds ratio from mixed-effects logistic regression models (time × group), adjusted for hospital department. A significant interaction term (p<0.05) indicates that the knowledge gain in the intervention group significantly exceeded the temporal change observed in the comparison group. * p<0.05. ** p<0.01. *** p<0.001.*

- *Effectiveness of the GIPCM on IPC Attitudes*

Table 5 presents the results of the DiD analysis of 15 attitude items. Overall, the intervention was associated with statistically significant improvements on 5 out of 15 items. The largest attitude effect was seen for the perception that hospital IPC guidelines are practical, increasing by 31.6 percentage points (from 43.7% to 78.2%) in the intervention group compared with only 2.9 percentage points (from 40.8 to 43.7) in the comparison group (DiD=+31.6 points; OR=4.62, 95% CI 2.52-8.47, p<0.001). There was also a substantial improvement in willingness to correct non-compliant colleagues (DiD=+23.2; OR=3.85, p<0.001), confidence in one's own ability to apply IPC measures (+18.3 points; OR=3.92, p<0.001), support for patient and family education on IPC (+15.5 points; OR=3.82, p=0.001), and belief that a co-created intervention is more likely to succeed (+12.7 points; OR=3.78, p=0.003).

In contrast, items with high levels of baseline endorsement, such as the belief that IPC is an important professional responsibility (85.9% in the intervention group at baseline) and that hand hygiene reduces infection spread

(88.0%), showed little additional change in these domains, as did confidence in institutional leadership's commitment to IPC and satisfaction with current IPC practices, neither of which improved substantially relative to the comparison group.

Table 5 Difference-in-Differences (DiD) Analysis of Favourable Attitudes Towards Infection Prevention and Control (N = 284)

No.	Attitude item	Baseline Interv. %	Endline Interv. %	Baseline Comp. %	Endline Comp. %	DiD (pts)	OR	95% CI	p
1	IPC is an important professional responsibility	85.9	91.5	83.1	88.0	+0.7	1.12	0.48-2.62	.789
2	Confident in ability to apply IPC measures	69.0	89.4	66.2	68.3	+18.3	3.92	1.92-8.01	<.001***
3	Hand hygiene reduces infection spread	88.0	93.0	85.2	89.4	+0.8	1.15	0.46-2.88	.762
4	Hospital IPC guidelines are practical	43.7	78.2	40.8	43.7	+31.6	4.62	2.52-8.47	<.001***
5	Leadership is committed to IPC	38.7	48.6	35.9	42.3	+3.5	1.22	0.69-2.15	.491
6	Willing to correct non-compliant colleagues	59.2	84.5	55.6	57.7	+23.2	3.85	2.01-7.37	<.001***
7	Supplies are necessary for IPC	93.0	95.8	90.8	93.7	-0.1	1.08	0.35-3.32	.895
8	Feel personally at risk of acquiring infection	77.5	81.7	73.2	76.1	+1.3	1.12	0.58-2.16	.738
9	Patients and families should be educated	73.9	91.5	69.7	71.8	+15.5	3.82	1.78-8.20	.001**
10	Reporting IPC breaches met with support	33.8	42.3	31.0	38.0	+1.5	1.11	0.62-1.99	.724
11	Motivated to participate in IPC training	84.5	90.1	81.0	85.9	+0.7	1.10	0.49-2.47	.816
12	Co-created intervention more likely to succeed	80.3	95.1	76.1	78.2	+12.7	3.78	1.55-9.22	.003**
13	Staff input should be considered in design	87.3	92.3	83.8	88.0	+0.8	1.14	0.48-2.71	.765
14	Improving IPC requires cross-cadre teamwork	90.1	94.4	87.3	90.8	+0.8	1.18	0.43-3.24	.748
15	Satisfied with current IPC practices	28.9	35.2	32.4	34.5	+4.2	1.22	0.68-2.18	.505

*Note. Comp. = comparison group; DiD = difference-in-differences; OR = interaction odds ratio from mixed-effects logistic regression models (time × group), adjusted for hospital department. ** p<0.01. *** p<0.001.*

➢ *Effectiveness of the GIPCM on IPC Practices*

Table 6 presents the DiD analysis of 15 IPC practice items. The intervention resulted in statistically significant improvements for 9 of the 15 items. The largest practice effect, as well as the biggest effect in this study, was for discarding sharps directly into the sharps container without recapping, which increased from 38.0% to 71.8% in the intervention group compared to 40.8% to 43.7% in the comparison group (+30.9 percentage points; OR=4.15, 95% CI 2.30-7.48, p<0.001). Hand hygiene before direct patient contact improved from 52.1% to 78.2% in the intervention group (+21.9 points; OR=3.32, p<0.001), and participation in IPC training or continuing professional development increased from 57.7% to 83.1% (+21.2 points; OR=3.65, p<0.001). Significant improvements of a similar magnitude were observed for peer support in reminding colleagues to comply with IPC requirements (+18.4 points; OR=2.95, p<0.001), appropriate removal and disposal of PPE after use (+17.6 points; OR=3.12, p<0.001), adherence to isolation precautions for transmissible infections (+13.4 points; p<0.0010, p<0.0011), waste segregation at the point of generation (+14.1 points; p<0.0012, p<0.0013), wearing appropriate PPE according to anticipated exposure (+13.4 points; p<0.0014, p<0.0015), and handling and transport of contaminated linen (+6.9 points; p<0.0016, p<0.0017). In contrast, hand hygiene after direct patient contact and after contact with patient surroundings, disinfection of reusable instruments, cleaning of shared equipment, and reporting of needle-stick injuries or documenting observed IPC lapses showed no statistically significant intervention-specific improvement, with baseline compliance for the first two items already comparatively high and reporting-related behaviours remaining persistently low in both arms.

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Table 6 Difference-in-Differences (DiD) Analysis of Infection Prevention and Control Practices (N = 284)

No.	Practice item	Baseline Interv. %	Endline Interv. %	Baseline Comp. %	Endline Comp. %	DiD (pts)	OR	95% CI	p
1	Hand hygiene before direct patient contact	52.1	78.2	47.9	52.1	+21.9	3.32	1.85-5.94	<.001***
2	Hand hygiene after direct patient contact	77.5	84.5	73.2	78.2	+2.0	1.15	0.58-2.28	.620
3	Hand hygiene after contact with patient surroundings	40.8	52.1	37.3	42.3	+6.3	1.38	0.78-2.44	.245
4	Wear appropriate PPE based on anticipated exposure	64.8	81.0	60.6	63.4	+13.4	2.45	1.36-4.41	.002**
5	Appropriately remove and dispose of PPE after use	62.0	83.1	58.5	62.0	+17.6	3.12	1.68-5.80	<.001***
6	Discard sharps directly into box without recapping	38.0	71.8	40.8	43.7	+30.9	4.15	2.30-7.48	<.001***
7	Segregate waste at point of generation	66.9	85.2	63.4	67.6	+14.1	2.65	1.40-5.01	.001**
8	Follow protocols for disinfecting reusable instruments	78.9	85.9	74.6	77.5	+4.1	1.25	0.62-2.52	.485
9	Clean and disinfect shared equipment/surfaces between use	49.3	59.2	45.8	49.3	+6.4	1.35	0.76-2.39	.280
10	Follow isolation precautions for transmissible infections	69.0	86.6	64.8	69.0	+13.4	2.85	1.48-5.48	<.001***
11	Handle and transport contaminated linen per protocol	60.6	71.8	57.0	61.3	+6.9	1.62	1.01-2.60	.045*
12	Report needle-stick injuries or occupational exposures	47.9	55.6	43.7	47.9	+3.5	1.22	0.70-2.12	.510
13	Participate in IPC training/CPD when offered	57.7	83.1	53.5	57.7	+21.2	3.65	1.95-6.82	<.001***
14	Remind or support colleagues to comply with IPC	53.5	76.1	50.0	54.2	+18.4	2.95	1.65-5.27	<.001***
15	Document or report observed IPC lapses in department	29.6	35.9	26.8	29.6	+3.5	1.18	0.65-2.14	.615

*Note. Comp. = comparison group; DiD = difference-in-differences; OR = interaction odds ratio from mixed-effects logistic regression models (time × group), adjusted for hospital department. Practice items were dichotomised as "often/always" (or "always" alone for the needle-stick reporting item) versus lower-frequency responses. * p<0.05. ** p<0.01. *** p<0.001.*

➢ *Perceived Barriers to Effective IPC Practice*

Table 7 displays the identified barriers to effective IPC practice in both study arms. Systemic and infrastructure-related barriers were the most common, followed by administrative and managerial, with individual and behavioural barriers being the least reported ones. There were no barriers that were uniquely associated with either the intervention or the comparison group (all p>0.05). At the same time, the most prevalent barriers were those related to a high patient/staff ratio with inevitable time limitations, which was reported by 89.4% of respondents. Other frequently occurring barriers included the stock-out of PPE and other consumables (85.6%), inadequate or intermittent water supply (80.6%), overcrowding or the lack of isolation wards (76.4%), and the absence of functioning waste-disposal systems (59.2%). In terms of administrative and managerial barriers, the most widespread challenge was the absence of a dedicated budget line for the hospital's IPC-related expenses, which was reported by 64.8% of respondents. Additionally, 53.9% of respondents indicated that the issue of language-specific SOPs was not adequately addressed in their facility, and 52.5% of respondents reported the lack of sufficient supportive supervision and feedback. As for individual and behavioural barriers, the most common barriers were related to protracted or routine non-adherence to hand hygiene (31.7%), skin irritation/dermatitis due to excessive hand rubbing (23.6%), and the perception of being at low risk of HAI (18.3%). Since these barriers were present across both study groups, they constitute general system-level challenges that cannot be addressed within the target setting specifically. This is especially true for the barriers related to resource limitations, which were reported consistently in both intervention and comparison facilities, thereby highlighting the need for broader action beyond the scope of individual facilities. This is in line with the observed changes in knowledge, attitudes, and practices (Section 3.3 -3.5).

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Table 7 Perceived Major Barriers to Effective Infection Prevention and Control Practice, by Study Arm (N = 284)

Barrier category and factor	Intervention n (%) (n=142)	Comparison n (%) (n=142)	Total n (%) (N=284)	OR	95% CI	χ^2	p
High patient-to-staff ratio (severe time constraints)	129 (90.8)	125 (88.0)	254 (89.4)	1.35	0.63-2.89	0.596	.440
Frequent stock-outs of PPE and consumables	124 (87.3)	119 (83.8)	243 (85.6)	1.33	0.62-2.85	0.713	.398
Inadequate or intermittent running water supply	117 (82.4)	112 (78.9)	229 (80.6)	1.25	0.69-2.26	0.564	.453
Overcrowded wards/insufficient isolation capacity	106 (74.6)	111 (78.2)	217 (76.4)	0.82	0.47-1.42	0.488	.485
Lack of functional waste disposal infrastructure	81 (57.0)	87 (61.3)	168 (59.2)	0.84	0.52-1.35	0.525	.469
Absence of a dedicated hospital IPC operational budget	96 (67.6)	88 (62.0)	184 (64.8)	1.28	0.79-2.08	0.988	.320
Lack of translated, localised SOPs (French/Swahili)	71 (50.0)	82 (57.7)	153 (53.9)	0.73	0.46-1.17	1.715	.190
Inadequate supportive supervision and audit feedback	70 (49.3)	79 (55.6)	149 (52.5)	0.78	0.49-1.24	1.144	.285
Forgetfulness or reliance on routine non-compliant habits	41 (28.9)	49 (34.5)	90 (31.7)	0.77	0.47-1.27	1.041	.308
Skin irritation/dermatitis from frequent hand hygiene	36 (25.4)	31 (21.8)	67 (23.6)	1.22	0.70-2.11	0.488	.485
Low perceived personal risk of healthcare-acquired infection	23 (16.2)	29 (20.4)	52 (18.3)	0.75	0.41-1.38	0.847	.357

Note. Frequencies represent participants identifying the factor as a "major barrier." Responses were not mutually exclusive. χ^2 = Pearson's chi-square statistic (df=1). None of the between-arm comparisons reached statistical significance (all p>0.05).

IV. DISCUSSIONS

➢ *Principal Findings*

This study assessed the effectiveness of a co-created multimodal behavioural change model, the GIPCM, in improving IPC-related knowledge, attitudes, and practices amongst healthcare workers in three hospitals in Goma, DRC, using a quasi-experimental, difference-in-differences design capable of isolating the intervention's specific contribution from any secular improvement that might have occurred in its absence. The key result is that the intervention was associated with statistically significant, differential improvement across a majority of the assessed knowledge and practice items, and a smaller but still meaningful subset of attitude items, suggesting that the GIPCM generated genuine intervention-specific behaviour change rather than a general trend affecting both study arms equally. The pattern of effects was, however, distinctly uneven, with improvement being most prevalent in knowledge and practice domains that had been assessed as weakest at baseline and in practices involving primarily the healthcare workers' agency, such as hand hygiene timing, sharps disposal, and PPE use, and less prevalent in practices dependent on material resources or established organisational routines, such as instrument disinfection, equipment cleaning, and incident reporting.

A plausible explanation for this pattern lies in the differential mechanisms by which the GIPCM's seven components act, with components that combined education (SOKO) and point-of-care reminders (KUMBUKA) having directly targeted knowledge and individually enacted practices and generated comparatively rapid change, and components oriented towards socialisation and leadership (RAFIKI, UONGOZI) plausibly requiring a longer period to reshape peer norms and accountability structures, and components dependent on system-level resource availability (MABADILIKO, MAJI) being constrained by the same supply, staffing, and infrastructural limitations that motivated the intervention in the first place, unlikely to be resolved within a single, relatively short intervention period, particularly in a health system operating under the resource constraints and instability characteristic of conflict-affected Goma.

➢ *Comparison with the Wider Evidence Base*

The results of this study align with the findings of the systematic review by Igwe et al. (2024) on the IPC interventions in African healthcare settings, which also revealed that combined/multimodal interventions typically yielded better results than isolated measures, although the review only used descriptive evidence from individual studies. They also align with the evidence from a broader range of studies informing the synthesis on multimodal IPC strategies by Sonpar et al. (2025). This review found that most studies reported improvements in hand hygiene practices or reductions in healthcare-associated infections, but the overall confidence in the evidence was only moderate due to the limited number of studies conducted in low- and middle-income countries; this study partially addresses this limitation by demonstrating the effectiveness of a specific set of multimodal interventions, including locally produced

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alcohol-based hand rub, in a similarly low-resource, conflict-affected environment.

The most compelling evidence corroborating the results of this study is provided by a stepped wedge cluster-randomised trial of a WHO-endorsed multimodal IPC strategy, which also involved the production of locally-made alcohol-based hand rub and was conducted across eight healthcare facilities in eastern Uganda (Nyawere et al., 2026 [the correct year needs to be specified by the author; see the note below]). The results of this trial, which utilised a similar set of educational and reminder interventions, showed that hand-hygiene compliance increased from 22.1% at baseline to 79.2% during the intervention period. While Nyawere et al. also implemented system-wide feedback and used locally produced hand-hygiene products, the current study's relatively limited system-level changes may explain the smaller observed improvements in hand-hygiene practices as compared to those reported in Uganda. Similarly, a cluster-randomised trial of infection-control link nurses involving systematic audit and feedback also yielded very positive results for hand-hygiene practices, with the intervention group demonstrating significantly better compliance with hand hygiene than the control group (Donati et al., 2020 [the correct year needs to be specified by the author]). This result provides further contextual validity for the effectiveness of the feedback and peer-support elements incorporated in the GIPCM, specifically the SIMAMIZI and RAFIKI components.

However, there is also evidence from other studies that complicates the interpretation of the results of this study. For example, a cluster-randomised trial of a hand-hygiene bundle implemented in two tertiary university hospitals by Aghdassi et al. (2020) showed that while hand-hygiene compliance before invasive procedures increased significantly during the intervention, this improvement failed to translate into an overall increase in hand-hygiene compliance by the end of the study period. Instead, the intervention was associated with a significant decrease in device-associated bloodstream infections. These mixed results are reminiscent of the findings of the current study, where hand hygiene before direct patient contact improved significantly while hand hygiene after patient contact and after contact with patient surroundings failed to improve overall. Thus, similar to the bundle used in the study by Aghdassi et al., the alcohol-based hand rub and the education and reminder interventions used in the current study appeared to have a limited impact on the healthcare workers' hand-hygiene behaviour, selectively improving compliance with some of the recommended hand-hygiene techniques. Finally, the Cochrane review of hand-hygiene interventions by Gould et al. (2017), which included 62 RCTs, concluded that the overall quality of evidence supporting hand-hygiene interventions was only moderate, which limits the extent to which the findings of this study can be generalised to other healthcare settings.

- *The Value of Co-Creation*

A distinguishing feature of this study was the use of a co-creation process rather than a predefined package of interventions to inform the behaviour change model. In line with a number of studies demonstrating the merits of experience-based co-design of health service models (Bate & Robert, 2006; Donetto et al., 2014), the participatory approach used in this research appeared to engender a degree of ownership of the proposed model among those involved, as evidenced by its consistently high relevance and acceptability ratings in Table 3, as well as the participants' very own description of the GIPCM as a model that "knows Goma", in contrast to "what is taught elsewhere". The observed extent of practice-level implementation appears to chime with this finding, and may partly account for the comparatively positive impact of the Goma intervention on health behaviours relative to some other external interventions reported in the literature. This, in turn, adds further credence to the notion that co-creation, by tapping into the target population's local know-how, may increase relevance, and thus "real-world" applicability, of health behaviour change interventions (Houghton et al., 2020).

- *Persistent Structural Barriers*

Despite the intervention's clear effects on knowledge and personally enacted practices, the barrier analysis (Table 7) showed that structural and health-system constraints, high patient-to-staff-ratios, PPE and consumable shortages, unreliable water supply and overcrowding, persisted and were reported at statistically indistinguishable prevalence in both study arms. This is consistent with reviews highlighting that healthcare workers adherence to IPC practices in low-resource contexts are determined as much by the availability of the means to adhere as their knowledge or motivation to do so (Alhumaid et al., 2021; Asghar et al., 2025). It also explains the pattern of intervention effects found here: practices which could be performed with available resources improved substantially, while those dependent on adequate supplies, water, or organisational report systems, such as instrument disinfection, equipment cleaning, and incident reporting, showed limited additional improvement despite GIPCM's explicit inclusion of system change and WASH components. This highlights that behavioural interventions, however well co-created, cannot substitute for the required material and organisational investment to remove the structural barriers to adherence they cannot themselves resolve.

- *Limitations*

Several limitations should be borne in mind in interpreting these findings. First, the quasi-experimental, non-randomised allocation of hospitals to intervention and comparison arms, while necessary to avoid within-facility contamination, cannot entirely exclude facility-level confounding; the significant baseline imbalance in hospital department distribution was addressed analytically but may not capture everything different between sites. Second, KAP outcomes were measured mainly by self-report, which can suffer from social desirability bias, particularly for practice items; the observational hygiene-practice checklist was intended to partly mitigate this limitation but was not the primary outcome measure reported here. Third, because the comparison hospitals were geographically close to the intervention hospital (except Minova), some diffusion of IPC awareness cannot be entirely excluded, which would, if anything, bias the estimated intervention effects towards the null. Fourth, it should be noted that the study measured KAP outcomes rather than clinical infection rates, so that the ultimate impact of the observed behavioural improvements on the incidence of nosocomial infection could not be directly established. Finally, the relatively short interval between baseline and endline may have been insufficient to detect the full effect of components, such as leadership engagement and system-level resourcing, that plausibly require a longer period to mature; longer-term follow-up would help establish whether the observed gains, and the observed gaps, persist, widen, or narrow over time.

V. CONCLUSION

This study found that a contextually co-created multimodal behavioural change model, developed in discussion with healthcare workers and stakeholders in Goma, DRC, had yielded substantial, statistically differentiated improvements across the majority of assessed IPC knowledge and practice indicators, and a sizeable subset of attitude indicators, compared to a comparison group, in the same period. Improvements were greatest in practices under healthcare workers' direct control, such as sharps disposal, hand hygiene prior to patient contact, PPE use, and participation in IPC training, and knowledge categories which had been identified as the weakest at baseline. This suggests the value of participatory, co-created approaches to IPC behavioural change, in addition to those generated in higher-resourced health systems, in fragile, conflict-affected settings.

However, the presence of substantial, statistically indistinct structural barriers across both study arms, and more limited improvements in practices relying on material or organisational systems, highlight that behavioural interventions can only address the root causes of inconsistent IPC practice in such settings; they will need to be paired with broader health-systems investment in staffing, supplies, water and sanitation, supportive supervision, and dedicated IPC financing, to have a lasting impact. Future research should follow this evaluation over a longer timeframe, assess whether the observed KAP improvements correlate with decreased healthcare-associated infection rates, and determine whether the cost-effectiveness of scaling the GIPCM, or similar co-created models, across additional facilities in the DRC and similar vulnerable health systems is viable.

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➢ *Competing Interests:*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

➢ *Ethical Approval:*

This study was approved by the Great Lakes University of Kisumu (GLUK) Scientific and Ethical Review Committee and the National Ethics Committee of the Democratic Republic of the Congo [approval/reference numbers to be inserted by the author], as well as by the administrations of the participating hospitals. All procedures were carried out in accordance with the 1964 Declaration of Helsinki and its later amendments.

➢ *Informed Consent:*

Written informed consent was obtained from all individual participants included in the study.

➢ *Data Availability:*

The datasets generated during the current study are available from the corresponding author on reasonable request.

➢ *Author Contributions:*

Akili Fataki Serge: Conceptualization, Methodology, Data acquisition and analysis, Writing - original draft. Manaseh Bocha and Faith Chesire: Supervision, Validation, Writing - review and editing.

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